More WL Issues

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for the /usr/WFIRST/HLS/WL group

General Notes

- Exposure Time Calculations
  - Maturity greatly improved from previous version, with some losses
  - Assumed for numbers presented here: WFIRST 1c configuration. This is 1.3 m off-axis with pupil mask
  - 4c3 is faster for WL (+17% collecting area; additional +10% speed since n_{eff} spec can be met with 160 s exposures instead of 180 s)
- Comparison of Sampling Cases
- I am not covering the jitter measurement requirement
  - We are iterating on this with the Project Office on how this can be relaxed
- Summary on what we could do without WL

ETC v7

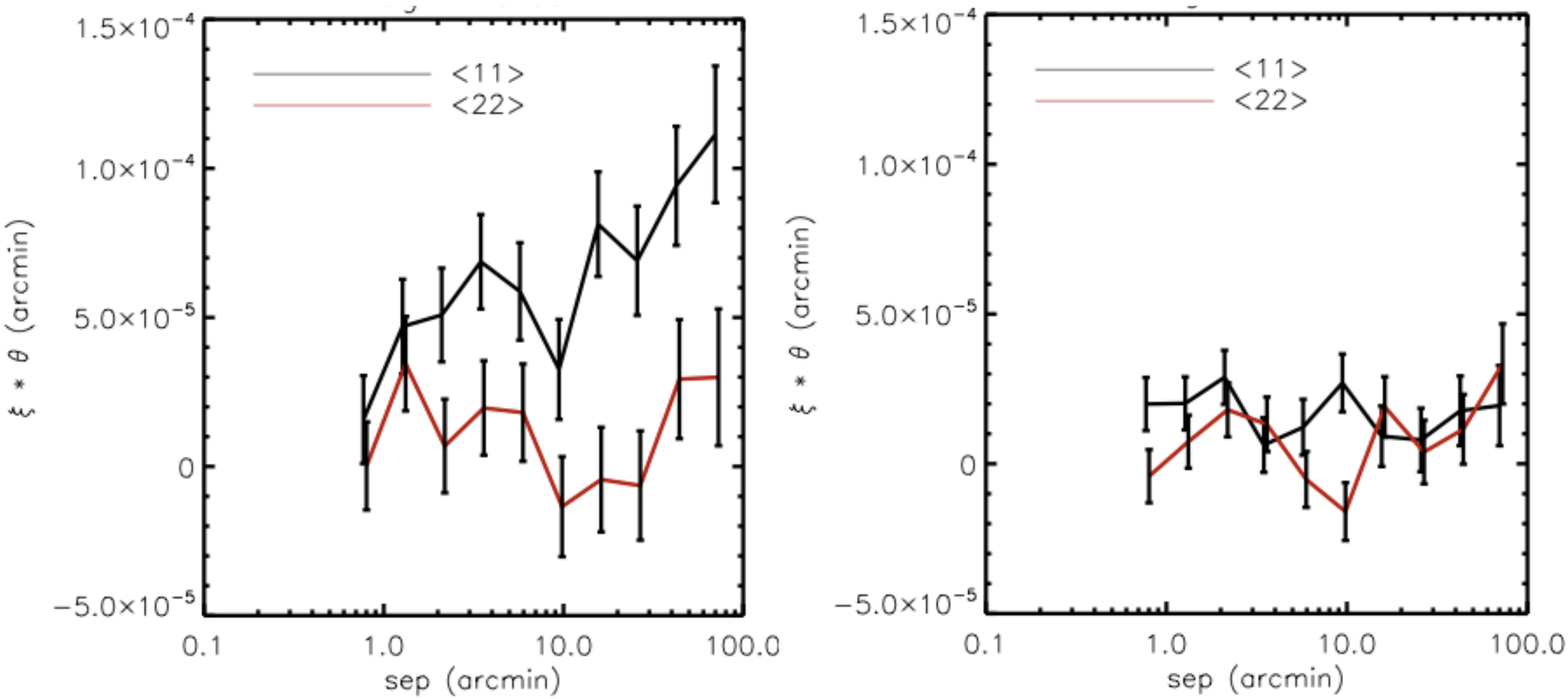
- Improvements (blue: v5→6, red: v6→7) via many exchanges with Project Office.
- Telescope throughput + detector QE curve from Project Office, added filter transmission and Galactic dust (includes pupil mask for off axis option).
- Sources of noise/background: zodi (ecl. lat/lon dependent), thermal emission, dark current, read noise (random + floor), propagates through unweighted SUTR fit.
- PSF: diffraction (+ obscuration if appropriate), aberrations, jitter, pixel tophat + diffusion.
- WL source galaxy catalog is currently COSMOS-based mock catalog (Jouvel et al 2009).
- Also has BAO/RSD mode – not the subject of this talk.

Current State of HLS Deep Survey Mode

- Exposure time in WFIRST 1c imager: 14 x 180 s
  - Split into 4 exposures in F1, 5 each in F2 and F3
  - Full sampling & shapes in F2/F3, F1 provides photo-z's
  - "Usable" galaxy is Res > 0.4, $\sigma_e < 0.2$, S/N > 18 per filter
  - $n_{eff} = 30.2$ gal/am^2 @ $\beta = 45°$, $\varepsilon = 115°$, E(B−V) = 0.1
  - 5σ pt src depth F1/F2/F3 = 25.94/25.89/25.90 mag AB
  - Parallel spectro mode gets "floor" of nP = 0.8 @ z=2 in 20 x 180 s
  - Survey rate is 2106 deg^2/yr
- Current tools are much more conservative and less idealized than on SCG. SCG was too optimistic, but we will gain some of this back.
  - Some assumptions are over-conservative, e.g. more sky better than this is available than we can cover in 2 years.
  - Spectro mode "floor" nP<1 is driven by tiling – should optimize.

Resolution Issues

- ETC v7 default (currently used) requires Res>0.4
- Example: SDSS/LBL co-adds by Eric Huff et al. (4 gal/am^2)
  - Star-galaxy shape correlation in i band (key systematic test)
  - Left: 0.25<Res<0.40, Right: 0.40<Res



Sampling: Basic Considerations

- The most important parameter is the number of cycles per pixel of the highest spatial frequency present ($u_{max}P$).
- Sampling depends on $u_{max}P$:
  - Oversampled: $u_{max}P < ½$ (no aliasing)
  - Weakly undersampled: $½ \leq u_{max}P < 1$ (some modes unaliased)
  - Strongly undersampled: $u_{max}P \geq 1$ (all modes aliased)
- Oversampled images can be treated as continuous.
- Weakly undersampled images:
  - Can be made oversampled by throwing out aliased modes, but with loss of resolution. (Might do this for e.g. sky subtraction/defect detection if $u_{max}P$ is far enough from 1.)
  - With multiple dithers, can recover full sampling and preserve all Fourier modes in the original image.

Combining Undersampled Images

- Multiple dithers are required to recover full sampling and cover chip gaps. If we use the same large-step dither pattern to do both:
  - Dithers are random (or at least non-ideal)
  - PSFs need not be identical (though this may happen anyway due to jitter)
  - Pixel grids may suffer relative distortions/rolls
- Determine required number of dithers using results from Barney Rowe's simulations (ApJ submitted).

OPTIMAL LINEAR IMAGE COMBINATION

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ABSTRACT

A simple, yet general, formalism for the optimized linear combination of astrophysical images is constructed and demonstrated. The formalism allows the user to combine multiple undersampled images to provide over-sampled output at high precision. The proposed method is general and may be used for any configuration of input pixels and point spread function; it also provides the noise covariance in the output image along with

Sampling for Various Options

- JDEMΩ is strongly undersampled at $\lambda < 1.31$ μm.
- Off-axis WFIRST ($D = 1.3$ m) is strongly undersampled at $\lambda <$ 1.13 μm.
  - Plan is to do shapes in F2 and F3 where we are weakly undersampled.
  - 1c @ 1.25 μm reaches MTF = 10^{-3} @ $uP = 0.86$.
  - Pupil mask improves sampling. In principle we could consider keeping sampling and f/ratio fixed.
- Euclid is strongly undersampled in principle ($u_{max}P = 1.07$).
  - But charge diffusion destroys the highest spatial frequencies.
  - @ 0.55 μm reaches MTF = 10^{-3} @ $uP = 0.80$.
- Ground-based wide field imagers use atmospheric phase fluctuations to recover full sampling (time averaged, high spatial frequency MTF $\rightarrow$ 0).

A Thought Exercise: WFIRST without WL?

- Deep mode HLS survey speed / exposure times:
  - Could reduce exposure time, e.g. 14x180 → 14x150 s: −0.16 mag depth (F2), −11% WL n_{eff}, −12% BAO n_{gal}, +16% coverage/yr. But this is a depth/area trade, is is not WL vs ~~WL~~.
  - Drop to 4 exposures per filter? (−0.12 mag depth in F2/F3, +17% coverage/yr) Would we be willing to go lower?
  - Switch to unfilled survey pattern? [Again this is not WL vs ~~WL~~.]
  - Switch to 2-filter HLS? (+40% or +56% coverage/yr)
- Pixel scale / sampling issues:
  - Without WL, would we make the ImC faster than f/15.9?
  - PRF wipes out Fourier modes preserved by the optics even at 1 μm. What is impact of loss of resolution to other science?
  - Note that ImC is already extremely undersampled at the bluest wavelength (2.8 cpp @ 4000Å)